Some Microscopical Observations of the Phonograph record.

By Persifor Frazer, Jr., A. M.

(*Read before the American Philosophical Society, April 5th,* 1878.)

As soon as the first wonder and delight at the performance of the phonograph had commenced to subside, physicists immediately set about thinking in what way this instrument could aid in their general researches.

This wonder was very natural, and it was greatest among those most versed in acoustics ; for it was a curious question why, with all the elaborate and delicate apparatus in the world, with the profundity of its designers, and the ambition of its employers ; with the attention of mankind directed so long to the problem of producing inanimate articulate speech ; and after the production of a permanent record of the characters of the sound waves of human voice upon smoked glass, no one had hit upon so simple an expedient for producing a record, which can be used to reproduce the sound.

The apparatus which Mr. Edison has employed is a cylinder covered with thin foil on which the blunted end of a needle or stylus impinges. The impression made by the point of the needle in the soft lead paper depends upon the path which that point was describing at the moment when the impression was made. By turning the cylinder with uniform motion so that the needle traverses a helical groove traced on its surface, at the same rate both when speaking and causing the instrument to speak ; the point of the stylus will travel over the same or nearly the same path, and the motions transmitted by the point to the centre of the diaphragm will be nearly the same in kind (though feebler in force) as before.

It was natural at once to think of investigating the forms left by the stylus in the soft lead foil under the microscope, and this has been done.

The following remarks are offered simply as a small contribution to an investigation which is clearly destined to occupy the minds of some of the ablest physicists for a long time to come.

By the kindness of Dr. Plush (Superintendent of the Philadelphia Local Telegraph Company), the following experiments were tried on his apparatus : After repeating the vowels and dipthongs A (ah), E (ay), I (ee), O (oh), U (oo), OI, OW, ă (as in *hat*), ĕ (as in bed), ĭ (as in *him*), ŏ (as in *Tobias*), ŭ (as in *put*), frequently enough to produce as uniform a result as possible, Dr. Plush spoke them into the mouth-piece, leaving spaces between each vowel and the end of the series ; so that there was no difficulty in picking out the different sound-records.

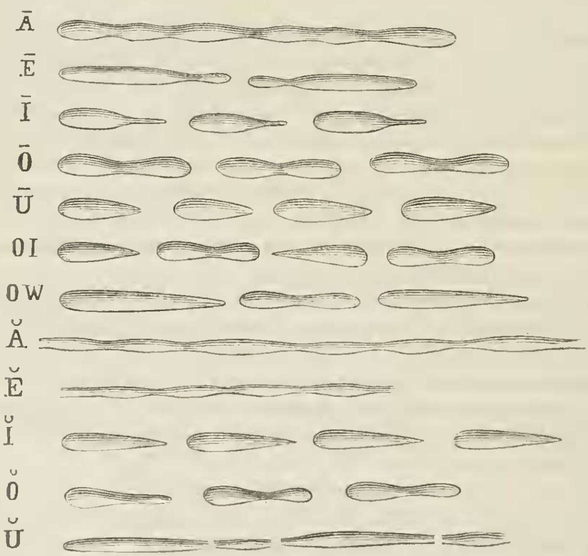
This record was then allowed to speak (its pronunciation being carefully noted and where necessary improved by another trial) two other records were added, thus filling up one sheet of the foil or matrix. When the articulation was deemed satisfactory the following records after having been made, were not subjected to the touch of the stylus for fear of obliterating or partially obscuring them.

These matrices were mounted on slips of glass, and were carefully examined under a low power of the microscope, the beginning and end of the record made by each vowel-sound being designated, by the letter appropriate to it.

In order to exhibit these records, a further modification of the mounting was made. The separate sounds were cut from the glass, separated, and glued in vertical lines upon the glass.

By means of reversing the direction of the projecting microscope and illuminating this record strongly by the condensers alone (a system of megascope projection well performed by Mr. Holman, of the Franklin Institute), not only are the impressions on the foil rendered distinctly visible but a line of them can be brought into focus at once and their local and accidental, compared with their fundamental and important differences.

The wood cut below will explain the nature of these differences :



*The characteristic of the sound A will be observed to be an alternation of

* Ten days after the above observations were made my attention was called to an article of Prof. Mayer, on the Phonograph in the last number of the *Popular Science Monthly*, in which he figures the impression made by "a" in bat and compares the section of the depressions made by the stylus in vibrating to this vowel with the shape assumed by the König's flame to the same sound.

There is one impression more on this record of Prof. Mayer than on the matrix which was the basis of these remarks; nor in the latter are the "dots and dashes" separated from each other so completely as thus seems to be in his experiment.

one long and two short sounds. Under the conditions of the experiment then it may be said to be dactylic (or anapæstic). In the cut there are two shorts followed by one slightly longer, and this twice repeated, though it is extremely probable that one set (i. e. one long and two short) constitute one complete excursion of the stylus which produces the sound. Ē resembles in the figure two Indian clubs laid with the handles together. This is the general character whenever seen, though the size and shape of the component parts are subject to variation.

In Ĕ there is in the cut but an indistinct resemblance to this apparently fundamental character. I have preferred, however, to have the drawing made without any bias by a third person rather than risk touching it to agree with an hypothesis. After viewing many scores of these dents and comparing them with the long Ē, I have no hesitation in saying that the forms are the same though much lighter. This latter fact is also attested by the manner in which the dents are run together, for this shows that the intensity of the sound was not great enough to cause a vibration which would clear the point of the stylus from the foil. The result is that the groove is continuous and the parts analogous to the depressions in long A are indicated by a widening of the groove.

The general resemblance between Ī and Ĭ is clear. As the drawings are not made to scale (the more accurate measurements being supplied below) the greater thinness of the characters impressed upon the foil by the light sounds does not distinctly appear. The appended micrometric measurements will, however, give information on this head.

Ō and Ŏ are like each other and unlike any of the rest, the shorter sound conforming to the rule above mentioned.

The same remarks will apply to a comparison of Ū and Ŭ that were made above in relation to Ĕ. A general resemblance with the short sound though the depressions are more tenuous is evident in OI.

A strong corroboration of the correctness of these symbols as indicating the given sounds with the especial conditions employed lies in the appearance of the record for OI, which is clearly seen to be made up of "*O*" "*ee*" or as pronounced O ĭ.

OW resembles "o" "u" strikingly.

It will be remembered that this drawing is not absolutely but approximately accurate. No scale or camera lucida was used.

Dr. E. J. Nolan, who was kind enough to draw the figures on wood, made his drawings entirely independently from myself, nevertheless they agree with those made by me in every detail except their better finish.

The narrow canals which separate or rather connect the larger depressions must be understood to result from the comparative quiescence of the point of the stylus at the moment when that point of the foil passed under it.

They are in fact nothing but the detached parts of the canal caused by pressing the point of the stylus into the helical groove. They may or may nor appear separating the different component parts of the same sound-record or of different sound-records, according as the loudness of the sound and the consequent extent of the excursion of the stylus enabled that portion of the instrument to clear the surface of the foil during the rapid revolution of the cylinder.

According to any reasonable hypothesis, the light vowel sounds and the long or heavy vowel sounds should bear a general resemblance to each other; but the latter should be more completely run together. This appears on the record.

It was intended to take casts of the depressions in gelatine or Canada balsam, in order that all parts of the solid forms may be examined at once, but naturally the shape of the depressions have only a secondary bearing on the subject since they are result of the dragging down by the stylus of the yielding lead paper in passing over a mathematical line.

Different substances or the same substance at different temperatures would naturally produce casts of entirely different character.

The following are some measurements of the lengths and widths of some of these forms. The depth was not measured:

Ā (Ah)

	Millimeters.	
Length	5.187	(Mean of six measurements.)
Breadth	0.532	" "
Distance apart	0.606	" seven "

Ē (ay).

	Millimeters.	
Length 1st of couple (large end on left)	7.3416	Mean of three measurements.
" 2d of couple (large end on right)	6.916	(Mean of three measurements.)
" 1st of couple (Small end on right)	1.2078	"
" 2d of couple (Small end on left)	1.2078	"
Breadth	0.266 to 0.798	——
Distance apart of small ends	0.798	Mean of three measurements.
" of large end	0.2881	Mean of six measurements.

I.

	Millimeters.	
Length of depression " neck	2.4738	Mean of three observations.
" Body	6.916	"
Greatest breadth	3.3416	"
Distance apart	1.862	Mean of three measurements.

Ō.

	Millimeters.	
Length 1st of couple..........	4.123	Mean of four observations.
" 2d of couple..........	4.721	
Breadth......	3.99	Mean of three
Distance apart...............	1.4896	" "
" between two of a couple	0.532	

Ū.

	Millimeters.	
Length....................	8.0598	Mean of three measurements.
Greatest breadth.............	2.66	———
Distance apart...............	3.192	Mean of three measurements.

OI.

	Millimeters.	
Distance apart...............	0.864	(Mean of four determinations.)

OW.

	Millimeters.	
Distance apart...............	1.596	(Mean of seven observations.)

ă.

	Millimeters.	
Length of long dent......	1.596	Mean of four measurements.
" 1st short dent..........	0.532	
" 2d " "	0.532	

ĕ.

	Millimeters.	
1st long depression......... ..	2.926	Mean of five measurements.
1st short "	1.064	
2d " "	1.064	
2d long "	2.926	

ĭ.

	Millimeter.	
Distance apart...............	2.075	Mean of five observations.

ŏ.

	Millimeter.	Mean of eight
Distance apart................	1.011	observations.

ŭ.

		Mean of eight
Distance apart...............	1.5561	measurements.

It would be well if a material could be discovered soft enough to offer the minimum resistance to the excavating action of the stylus, yet which could be hardened without distorting the shape of the depression.

Some Tables for the Interconversion of Metric and English Units.

By Persifor Frazer, Jr., A. M.

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Capt. Kater, in 1821, as a member of the Royal Standard's Commission, appointed in 1818, made the determination of the meter to be 39.37079 inches. This was adopted by the Commission and was embodied into the statute of the British Parliament enacted in 1824, establishing the platinum standard meter in Paris as in length equal to 39.3708 inches of brass at the temperature of 62° Fahrenheit, the platinum standard being at 0° Centigrade, or 32° Fahrenheit, the temperature of melting ice.

Capt. Kater's value was again sanctioned by law in 1864.*

In 1866, the Royal Ordinance Survey, adopted 1 meter = 39.370432 inches, on the authority of Col. (then Capt.) A. R. Clarke, Superintendent of the Office of the Survey at Southhampton.

In 1869, the more recent Royal Standard's Commission, under the Presidency of Astronomer Royal Airey, reported comparative tables, founded on Kater's value, which were published in a Parliamentary Blue Book, and may be found at the end of the second Report of the Royal Standard's Commission, published in that year.†

The subjoined work was undertaken to supply a want which every physicist and chemist, and, indeed, very many artisans and manufacturers have felt, for a set of convenient and consistent tables for converting various values of measure and weight from one into the other of the two systems between which at present the calculations of the greater part of the civilized world, both in science and trade, are divided.

Every one knows that a multitude of tables for this object are already in

* When the use of the metric sytem was rendered permissive in Great Britain so far as related to contracts.

† Extracts from a private letter from President F. A. P. Barnard, of Columbia College, New York.